FRV 40: A U.S. FISHERIES RESEARCH SHIP

James M. Meehan
FRV 40 Mission Manager
Office of Science and Technology
National Marine Fisheries Service
National Atmospheric and Oceanographic Administration

John M. Hotaling
FRV 40 Deputy Program Manager
Office of Science and Technology
National Marine Fisheries Service
National Atmospheric and Oceanographic Administration

ABSTRACT

Fisheries research vessels (FRVs) are characterized by their capability to conduct stock assessments and biological sampling of fish, shellfish, marine mammals and other species, as well as to collect related oceanographic samples and data on the same cruise. They are required to tow large mid-water and bottom trawls, conduct hydroacoustic surveys, cast and recover biological and oceanographic samplers and instrumentation, and have laboratories and facilities for processing the samples and data. The existing U.S. fleet of eight FRVs, all owned and operated by the National Atmospheric and Oceanographic Administration (NOAA) within the U.S. Department of Commerce, has become functionally obsolete with reliability and safety decreasing while maintenance costs are increasing. A new fleet of multi-functional ships, capable of supporting 24-hour, interdisciplinary research is required. This paper includes the design considerations for incorporating the scientific needs and requirements into a quiet vessel with low underwater radiated noise, modern research laboratories and instrumentation, sea-kindliness for manipulative experimentation and modern safety standards for U.S. FRVs (e.g. US Coast Guard, American Bureau of Shipping, SOLAS, Federal Communications Commission, US Public Health Service). The projected future needs for fisheries data and how the new FRVs will contribute to the health and management of the National and World fisheries will be discussed.

INTRODUCTION

Members of the NOAA Fisheries Research Vessel (FRV) Team collaborated to balance scientific and operational mission needs with state-of-the-art naval architecture and marine engineering technology. They defined a class of ships, to replace the aging vessels in the existing fleet, which will meet growing and increasingly sophisticated at-sea data requirements over their 30-year life span.

The mission of the National Marine Fisheries Service (NMFS) within NOAA is to build sustainable fisheries, recover protected species, and protect habitats essential to living marine resources. This mission can not be accomplished without safe, reliable ships. FRVs are central to conducting the at-sea research and monitoring used for sound management of the United States's living marine resources. Domestic commercial landings in 1997 were valued at $3.5 billion and, in that same year, nearly 9 million people made 68 million marine recreational fishing trips. The economic vitality of coastal communities throughout the United States depends on the health of these resources. Global food security is contingent upon each country's commitment to building prosperous, but sustainable fisheries. It is incumbent on the U.S. to further the international standards for resource conservation. Introduction of these new FRVs into the fleet assures that the U.S. can continue in this role.

NOAA's current fleet of ships have served their Nation well, but have aged beyond their useful lifetime and are technologically obsolete. Formulating and implementing a program to modernize the fleet has been a task of significant proportions. Ships of the existing fleet could not be used as a template for the new FRV because they reflect the fisheries development mission focus of the Agency from decades ago. Each of the five NMFS Fisheries Science Centers had different requirements for a research platform to be effective for their assigned fisheries. This program required the creation of a new strategy which placed heavy emphasis on evaluating the specific research needs in the context of the current Agency mission, resources and priorities. Alternative systems were explored, market survey conducted, and cost and risk management opportunities were extensively evaluated.

The ultimate product of these efforts was a strategy to modernize the fleet by constructing state-of-the-art FRVs, using a modified sister ship approach to meet the core mission needs of the Agency. Multiple mission requirements were consolidated and rationalized into a single innovative ship design. Cost savings of the sister ship approach, through economies of scale during the construction phase, commonality of interchangeable parts, and operational flexibility, are expected to be substantial. The ships are designed to meet international standards for radiated noise, which will maximize the efficiency and accuracy of all surveys involving animals subject to disturbance by vessels radiated noise. Implementation costs of the quieting features were dramatically reduced by shifting much of the risk for meeting much of the stringent radiated noise levels from the shipyard to the government. In turn, the government's risk was mitigated by contracting some of the United States' most knowledgeable experts in noise control to assist in the propeller design and hull model testing from the Naval Ship Weapons Center's Carderock Division. Model tests of the propeller and hull form not only met, but exceeded all expectations. Recognizing the value of our human capital, the ships were designed to meet industry and international standards for research ship safety.

Feasibility studies were conducted for proof of the design concept. Peers from domestic and international entities were consulted to put the design, acquisition approach, and overall modernization plan to the test. Input from world-wide authorities on research ship design and construction was incorporated into the program, with the aim of achieving significant cost savings and risk mitigation in the overall strategy.

ADVANCES IN DESIGN AND REQUIREMENTS

Modern Fisheries Research Vessels (FRVs) must be dedicated ships with state-of-the-art technologies and capabilities to increase the accuracy and precision of sample and data collection and analysis. Among these requirements are low underwater radiated noise, especially in the low frequencies; the capability to tow bottom trawls in depths as great as 1,000 fathoms; the capability to tow large pelagic nets at speeds of at least 5 knots;

dedicated laboratories and sampling equipment to support multi-discipline research; "seakindliness" so that researchers may perform tasks requiring manipulative skills; and computer system capabilities for logging, interfacing, and analyzing the variety of information collected. Modern communication capabilities are required to transfer raw and analyzed data between the ship and shore facilities in near real-time. Without such modern, dedicated fishery research ships, the data provided to both national and international resource managers will decrease quantitatively and qualitatively.

A modern fisheries research ship should be multi-functional to support inter-disciplinary research, e.g., conduct fish stock assessments using hydro-acoustics and trawling techniques, fisheries biology and oceanography, environmental studies, and manipulative experimentation on the same cruise. Multi-functional, inter-disciplinary research requires that the ship be capable of operating 24 hours per day and supporting a scientific party of at least 15-20. The ship should be capable of a minimum trial speed of 14 knots to efficiently cover vast expanses in a timely manner. To operate in remote areas of the North Pacific the ship should have a minimum endurance of at least 40 days and a minimum cruising range of 12,000 nautical miles. It must be powerful enough to tow large pelagic trawls at five knots, yet have low underwater radiated noise during hydro-acoustic surveys at 11 knots. The capability of maintaining a trackline at speeds of less than half a knot while towing equipment and maintaining accurate station-keeping with sampling gear over the side are also important requirements.

Adequate wet, dry, and electronic laboratory spaces need to be available for processing samples and data. Scientific freezer and dry storage areas need to be accessible and adequate for the storage of specimens and equipment. Fishery and oceanographic deck equipment to include trawl, oceanographic, hydrographic, and special purpose winches rigged A-frames or J frames with multiple blocks, is essential. A stern gantry and associated gallows are required for trawling. A large crane is required aft to lift nets filled with fish and move heavy equipment around the working deck and over the side. Due to the remoteness of certain survey areas a redundant second crane is desirable. This would prevent a cancellation of the cruise in case the first crane breaks down. The aft working deck must be large enough to accommodate fishing operations and include a trawlway. The ship should have tie-downs and services for specialized portable vans.

The current feasibility design for the first new NOAA FRV represents a synthesis of several years of work which can be summarized simply. However, it should be noted that a multitude of detailed considerations have produced NOAA's approach to a modern FRV.

Some of the advances incorporated into the design of the first FRV, which will be used at NMFS' Alaska Fisheries Science Center, are:

1. Low underwater radiated noise levels;

2. Low internal noise levels;
3. Reduced manning levels;
4. Meets stringent domestic and international safety standards
5. Multi-functional survey ability with an array of trawls and scientific samplers;
6. Specialized handling equipment;
7. Good seakeeping;
8. Genset redundancy;
9. Stable power supply;
10. Automatic data logging;
11. Computer and work station facilities;
12. Electromagnetic compatibility throughout the ship.

Principal design characteristics and standards are listed in Table 1. and general arrangements and shown in Fig. 1.

DESIGN AND SPECIFICATIONS

Hull Form/Propeller Design/Cavitation Tests

Early concept and feasibility studies pointed to two high risk areas which needed attention if this ship was to perform its mission both quietly and efficiently. These were hull form and propeller design. The FRV acquisition team devoted significant resources and time to the development of both the hull and propeller. First and second round National requirements refinements were conducted to assure ourselves that the overall dimensions and displacement could accommodate all of the NMFS requirements and leave construction and service life margins available. With length, draft and speed defined, the propeller parameters were investigated to assure a solution was possible within the given constraints. Initial selection of a propeller diameter was needed to leave the designers flexibility and still not make the ship unacceptably deep. Although large for a ship of this size, it was determined a propeller diameter of 3.9 M was necessary. These are not simple trade offs, because the vessels frequently work inshore and in shallow waters. Small additional amounts of draft eliminate large scientific survey area in much of the coastal EEZ, as well as restrict the marine facilities she can enter.

<u>Table 1. Principle Characteristics and Standards</u>

Maximum Length:	65 meters
Maximum Beam:	15 meters
Maximum Draft:	6.0 meters
Air Draft:	Less than 41.4 m
Trial Speed:	14 knots

Range at 12 kts:	12,000 nm
Endurance:	40 days
Diesel Electric Power installed:	4540 Kw
Single screw fixed pitch propeller;	
Direct current, tandem main motors:	2250 Kw
Complement: 19 scientists and 19 crew	38 total
Hydroacoustically quiet:	ICES Standard

Centerboard for transducers
ABS Loadline
ABS Classification A1E, AMS, Circle E
ABS Class ACCU Engine Room Automation
ABS Ice Class C0
46 CFR Subchapter U, "Oceanographic Research Vessels" regulations
SOLAS Regulations
MARPOL Regulations
IEEE 45 EMC standards & Canadian cable spacing matrix

The hull form was selected and developed balancing these competing demands: single screw, 14 knots, large cut away stern with skeg to assure excellent propeller flow, minimal bubble sweep down in the hull mounted transducer area, sea-kindly motions for scientific complement, drag on the keel for trawling control, minimum resistance for life cycle fuel efficiency, and accommodation of a large centerboard for transducer deployment below the hull. The following illustrations show the computer modeling which lead to the final model shape. The model itself, shown hanging in the straps at the David Taylor Model Basin in Carderock, Maryland (Fig. 2.), was scaled at 1/13th of the design size. This allowed initial testing to use a stock propeller. Flow visualization tests indicated some areas of concern which were corrected. Resistance and powering model runs were conducted in the spring of 1999. Overall resistance was reduced by approximately 8% through application of seemingly minor, but sophisticated, design modifications. This represents a huge fuel savings potential over the life of the vessel.

Parallel and in conjunction with the hull testing and development, the propeller design was started. The overall propeller design criteria was to have good efficiency at two extremes; free running 14 knots, and trawling at four knots with 160 KN additional net drag, and the full scale propeller could not cavitate at the 11 knot hydroacoustic survey speed required by the ICES standard. A design goal was to develop a cavitation free propeller in the trawling condition. This was not a firm requirement because most of the propeller consultants indicated that the state of the art may not make this achievable.

Early indications also pointed to a controllable pitch propeller which was thought to be necessary to meet the criteria as well as reversing and maneuvering needs. Trade off studies were then conducted which allowed selection of a fixed pitch propeller based upon very small efficiency losses in the operating extremes and availability of quality motor speed and reversing control from electric drives. The penalty of life cycle maintenance of a CPP, the additional hub diameter, and the risk of hub noise, led us to a fixed pitch design choice.

Propeller test results in the Naval Surface Weapons Center's Large Cavitation Chamber in Memphis, Tennessee indicated that we have achieved our requirements, met our goals, and more! The test results indicate that we may achieve our cavitation free goal in the trawl condition.

For these tests the model was hung in the vacuum chamber slip stream (Fig. 3.). Figure 4 shows the model propeller operating in a cavitation simulation well above the design point. Test data confirmed that no cavitation will occur at or above our operating conditions.

Propulsion/Machinery Configuration

The FRV is configured as a diesel electric propulsion plant.

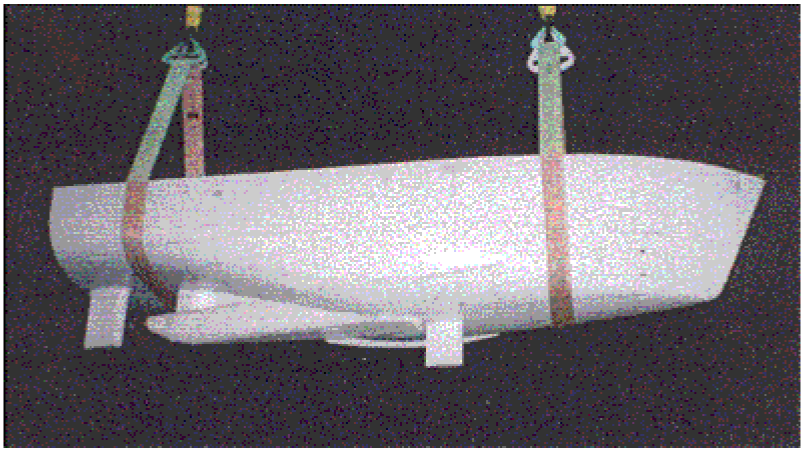

Fig. 2. Scale model of new NOAA FRV hanging in the straps at the David Taylor Model Basin in Carderock, Maryland

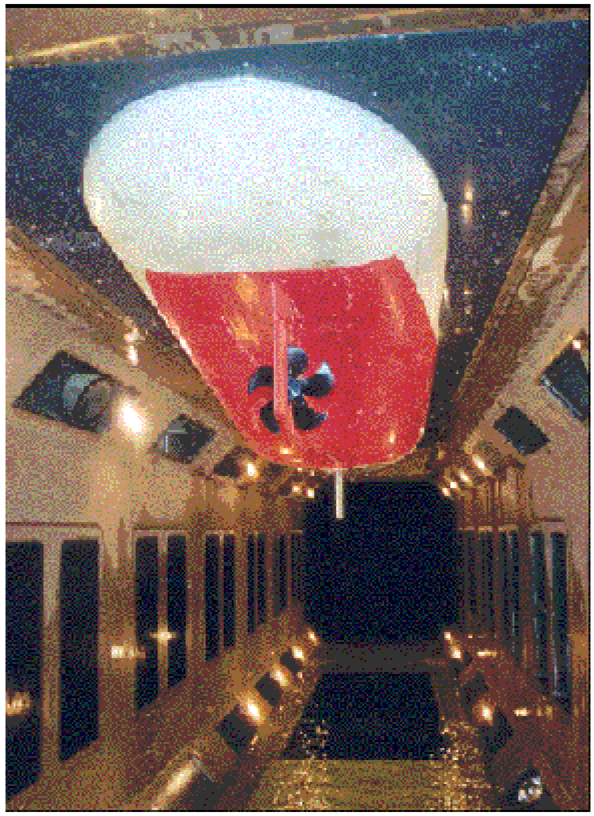

Fig. 3. FRV model hanging in the vacuum chamber

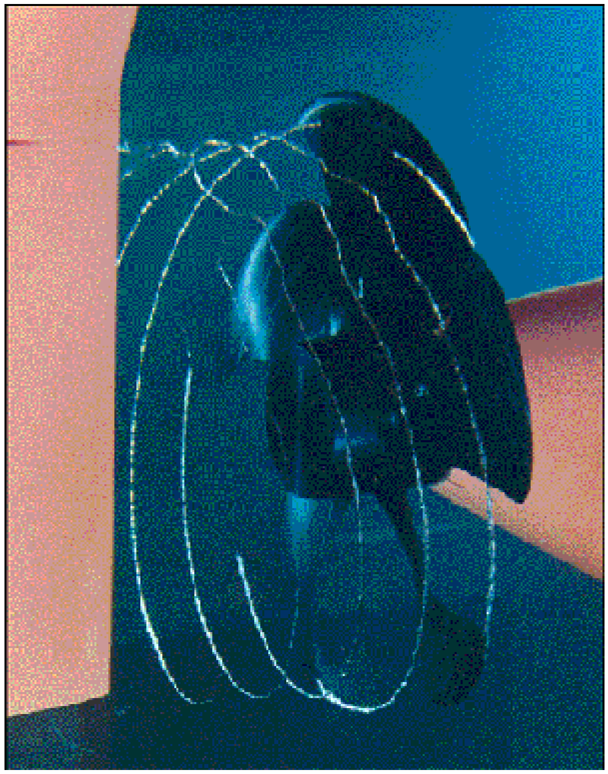

Fig. 4. Test propeller operating at twice the design point for trawling operations.

This is dictated by the need to achieve ships underwater radiated noise levels that will not impact hydroacoustic survey accuracy. This configuration allows the diesels to be effectively isolated from the hull with double isolation mounts on a rafted mass. These spring mounts are tuned to eliminate the noise frequencies from becoming water borne. These frequencies and decibel limits were dictated by the work done in the international arena by ICES based upon numerous fish and marine mammal hearing ranges and the desire to not modify the wildlife's behavior at close, 20m, ranges.

By accomplishing these objectives the scientific accuracy during surveys of both commercially harvested as well as protected species can be improved and maintained in long data series. NMFS' further objective is to also create a class of ships to allow close calibration between vessels. This will significantly reduced error introduced into the long term data sets when different vessels are used in surveys. NMFS can move ships into different ecosystems and be afforded the flexibility to manage ship deployment, mission needs changes, and operational costs in a more rational manner.

The single class of FRVs will also allow for fleetwide sparing, logistical support from a common design and spares basis, and development of a cadre of deck officers, engineers and crew who can easily be shifted from platform to platform because of common training and experience. Augmentation of specific crew members is expected to be much more efficient when supplied by a pool of seamen trained for this class of FRVs.

Propulsion machinery configuration is the core of this approach. Diesel electric allows quiet operations and other advantages. Four diesels, two larger and two smaller, are coordinated on a common electrical distribution buss. Load analysis indicated that no single operational design point could be anticipated. Mission analysis lead the designers to father-son diesels which can be coordinated to provide efficient operating points at different load generation requirements.

The diesel generators supply AC power to the common electrical buss, which in turn supplies both the hotel and scientific loads, as well as the main propulsion motors. Direct Current tandem propulsion motors were favored in the design guidance for two reasons. First, DC propulsion motors are used in the only existing application we found which has been demonstrated to meet the ICES radiated noise requirements. Our investigations of other similar ships in the international community did not provide any examples of other propulsion types or configurations which have met the criteria. Second, the tandem motors allowed arrangements low in the ship to minimize shaft drag within the skeg while providing a redundant and desirable take home motor. In fact, the ship could perform a significant portion of her mission at less than 1 Mw of main propulsion, thereby allowing for continued operation if one motor is down for some reason.

Safety

The safety of personnel and the ship was of primary importance in the design of the ship. This is doubly so, given that up to 50% of the complement would usually be non-marine personnel.

The ship has been designed to meet all modern safety standards including the international Safety Of Life At Sea conventions for vessels in international trade, the US Coast Guard regulations for Oceanographic Research Ships of this size, and the American Bureau of Shipping underwriting classification society rules.

Some of the salient specifications relating to safety were:

1. Automatic fire and detection systems;
2. $C0^2$ fire extinguishing systems in all machinery spaces including the bowthruster room, paint store;
3. Fire extinguishing systems in the laboratory spaces;
4. Hose reels within the accommodation;
5. Automatic pressurized sprinkler system in accommodation;
6. Subdivisions and watertight doors;

7. Self righting rescue boat;
8. Closed circuit TV with numerous remote cameras;
9. Internal communications, phones, talk back speakers, and PA systems;
10. Engine room automation with remote alarm panels.

The main working deck is potentially the most dangerous area on the FRV because of the need for non-marine scientific personnel to be on deck during many of the survey operations. The main trawl winches and the oceanographic winch will be installed below the main deck. This provides a measure of added safety by limiting wires on the main deck and increasing the safe working life of this equipment because it is protected from the weather. The main working and side decks are covered with non-skid surfaces to provide a slip-free safety deck.

Reduced Manning Levels

The basic construction specifications include both safety and reduced manning criteria which will return a significant benefits to NOAA over the vessel's life. Reduced manning levels, which are at the minimum required crew size of 13, keep operating costs to a minimum without compromising ship safety. Fishing operations are supported by six additional crew members attached to the ships complement as able bodied seamen. These 19 people are organized to fully support the scientific party in around the clock operations, mindful of crew fatigue, back up, and the necessity to augment departmental needs if automation is inoperative, weather dictates more workforce needs, or the scientific operating tempo changes. The scientific party also consists of 19 bringing the total complement to 38.

Slow Speed Maneuverability

Many of the fisheries and oceanographic operations are accomplished at slow speeds which require maneuverability. The FRV is expected to have outstanding maneuvering characteristics at slow speeds. The large diameter propeller will have excellent flow into the entire circumference. When coupled with the oversized high lift rudder, and assisted by an azimuthing bow thruster, helm responses at slow speeds are expected to be excellent. Engine control for RPM and reversing commands will be extremely quick, smooth and reliable because of the modern electric drive technology. On the other hand, the vessel is expected to also have very stable track line capability due to the skeg, drag on the ships keel, and the high lift rudder.

Seakindliness

Bilge keels along with an anti-roll tank will minimize roll motions.

Noise

Noise from mechanical systems must be strictly managed to prevent internal noise from conducting through a sound path into the water. engine room equipment, distribution systems including ventilation systems, main engine exhaust, and hydraulic systems must all be noise control treated. Internal joiner bulkheads will have damping materials, and damping tiles will be installed on the shell plate in the engine room

Vibration

Vibration from the main diesels is the main obstacle to achieving the aims of the specifications. Diesel Alternators are mounted on specially designed rafts

Underwater - Radiated Noise

The need for low noise levels came about because of increasing concern over the effects of underwater noise radiated from research vessels. For purposes of fisheries research, especially stock assessment surveys, it is important that the natural distribution of fish should be disturbed as little as possible during survey operations. In addition where acoustic surveys are undertaken it is necessary to assure that the fish target strength distributions and echo-integrator results are free of bias due to high-frequency noise. The ICES Study Group on Vessel Noise determined that the critical low frequency band of high sensitivity hearing for fish is between 20 Hz and 1.2 Khz. For high frequencies the levels are based on preventing noise contamination of fish echoes at 38 KHz.

The resulting Specification is shown illustrated Figure 5.

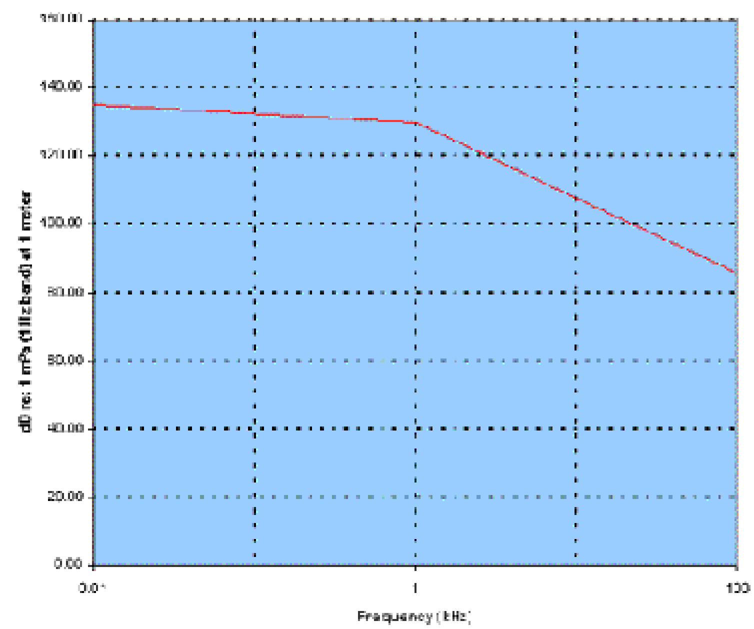

Fig. 5. ICES radiated noise standard

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